PB80-187941

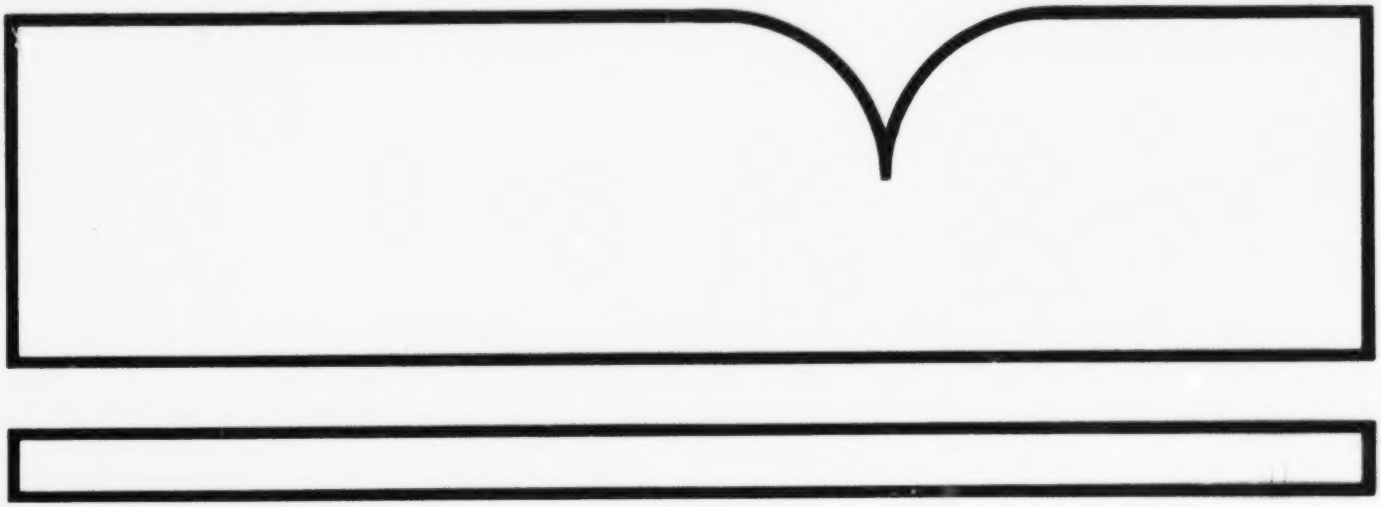
# Direct-Seeding of Commercial Trees on Surface-Mine Spoil

Kentucky Univ.
Lexington

Prepared for

Science and Education Administration
Washington, DC

Apr 80



U.S. Department of Commerce
National Technical Information Service
NTIS

USDA

United States
Department of
Agriculture

Science and Education
Administration
Cooperative Research
Washington DC 20250

CR 12

PB80-187941

EPA

United States
Environmental Protection
Agency

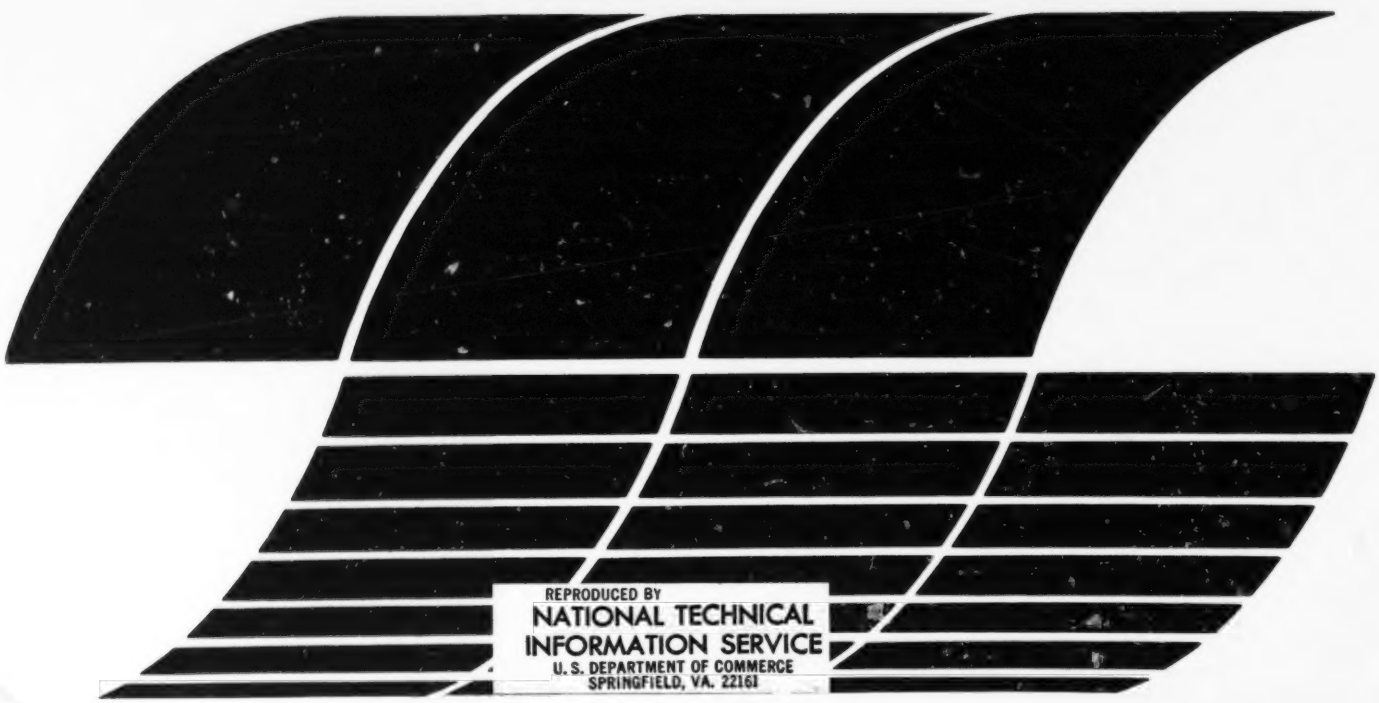
Industrial Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/7-80-073
April 1980

Research and Development

# Direct-Seeding of Commercial Trees on Surface-Mine Soil

## Interagency Energy/Environment R&D Program Report



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

## RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the INTERAGENCY ENERGY-ENVIRONMENT RESEARCH AND DEVELOPMENT series. Reports in this series result from the effort funded under the 17-agency Federal Energy/Environment Research and Development Program. These studies relate to EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy systems. The goal of the Program is to assure the rapid development of domestic energy supplies in an environmentally-compatible manner by providing the necessary environmental data and control technology. Investigations include analyses of the transport of energy-related pollutants and their health and ecological effects; assessments of, and development of, control technologies for energy systems; and integrated assessments of a wide range of energy-related environmental issues.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EPA-600/7-80-073
April 1980

# DIRECT-SEEDING OF COMMERCIAL TREES ON SURFACE-MINE SPOIL

by

Donald H. Graves, Stanley B. Carpenter and Robert F. Wittwer
Forestry Department
University of Kentucky
Lexington, Kentucky 40546

EPA/IAG D6-E762
SEA/CR No. 706-15-7

Project Director

C. O. Little
Associate Director
Agricultural Experiment Station
Lexington, Kentucky 40506

Program Coordinator

Eilif V. Miller
Mineland Reclamation Research Program
Science and Education Administration - Cooperative Research
U. S. Department of Agriculture
Washington, DC 20250

Project Officer

Ronald D. Hill
Resource Extraction and Handling Division
Industrial Environmental Research Laboratory-Cincinnati
Cincinnati, Ohio 45268

This study was conducted in cooperation with the Science and Education Administration, Cooperative Research, USDA, Washington, DC 20250.

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

## DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory-Cincinnati, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The views and conclusions contained in this report are those of the authors and should not be interpreted as representing the official policies or recommendations of the Science and Education Administration-Cooperative Research, U. S. Department of Agriculture.

## FOREWORD

When energy and material resources are extracted, processed, converted and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

Reported here is a study of direct seeding of several tree species on coal mine spoils. The results of this study should be of interest to those persons planning and/or directing a vegetation program for surface mines. For further information contact the authors or the Industrial Environmental Research Laboratory-Cincinnati.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

## ABSTRACT

Two small-seeded species, Paulownia (*Paulownia tomentosa* (Thunb.) Siev. & Zucc.), and European alder (*Alnus glutinosa* (L.) Gaertn.) and three large seeded species, northern red oak (*Quercus rubra* L.), pin oak (*Quercus palustris* Muenchh.), and bur oak (*Quercus macrocarpa* Michx.) were direct-seeded on three aspects on minesoil in eastern Kentucky. Treatments included four mulch applications - water-borne fiber mulch (w.f.m.), hardwood bark, bark and manure, and composted municipal waste; two fertilizer applications--224 and 448 kg/ha of 16% N, 32% $P_2O_5$, 8% $K_2O$; and two rates of herbaceous vegetation seed--11.2 and 22.4 kg/ha. A one-to-one ratio of yellow sweetclover (*Melilotus officinalis* (L.) Lam.) and a tetrablend ryegrass (*Lolium perenne* L.) was used. Growth and survival were evaluated during two consecutive growing seasons.

Survival for both Paulownia and European alder was poor (2%). Survival for northern red oak, bur oak, and pin oak was much higher at 34%, 50%, and 46%, respectively. Initial germination for all species was significantly higher on the warmer south-facing aspect. Mulching increased survival of all species, with the composted municipal waste mulch ranking the highest and w.f.m. the lowest. Mulching also enhanced growth, with bark/manure mulch increasing growth the most. Survival of all species decreased when fertilizer was added but height growth was increased. The effect of competition appeared to affect germination more than any other variable. Those plots without herbaceous competition survived best. The high seed rate (22.4 kg/ha) was second followed by the 11.4 kg/ha seed rate. The higher seed rate appeared to act as a mulch, reducing evaporation losses, thus providing more moisture for the tree seedlings. Competition appears to reduce height growth of all species with increasing application rates of herbaceous cover. Although survival was low for Paulownia, it grew the best averaging 65.0 cm. Pin and bur oak ranked next with mean heights of 12.1 and 12.5 cm, respectively. Northern red oak grew the least averaging 9.2 cm.

Overall, the oaks as a group survived and grew well, indicating that direct-seeding oaks may be more practical than planting bare-root stock or containerized seedlings.



This report was submitted in fulfillment of Grant No. 706-15-7 by the Forestry Department, University of Kentucky under the sponsorship of the U. S. Environmental Protection Agency. This report covers the period July 22, 1977 to November 30, 1979 and work was completed as of December 1, 1979.

CONTENTS


Foreword . . . . . iii
Abstract . . . . . iv

1. Introduction. . . . . 1
2. Conclusions . . . . . 2
3. Recommendations . . . . . 3
4. Methods . . . . . 4
5. Results and Discussion. . . . . 6

Germination and Survival . . . . . 6
Table 1. . . . . 6
Table 2. . . . . 7
Height Growth. . . . . 8

References. . . . . 9

## SECTION I

## INTRODUCTION

Surface-mining accounts for the largest annual reduction of commercial forest land in Kentucky. Most reclamation efforts are directed toward the establishment of grasses and legumes since they tend to rapidly establish and stabilize the site to reduce erosion and sediment loss. Additional time and labor is required for tree planting as compared to seeding grasses and legumes and mortality is usually high, adding more costs to an already expensive operation. Therefore, unless better methods of establishing trees on minesoil are found, Kentucky and other states will have a difficult time in meeting OSM requirements in establishing a forest land use category in final reclamation plans. Direct-seeding could provide the method for including more trees in minesoil reclamation.

Several thousand acres of trees have been established in the southeastern United States by direct-seeding.[1] Advantages of direct-seeding include lower costs, less labor and equipment and ease of ability to regenerate remote or inaccessible areas.[2] Direct-seeding has often failed to produce adequate stands of seedlings on minesoil for different reasons. Dessication of germinating seedlings, rodent and bird predation and erosion and siltation are often blamed for direct seeding failures.[3]

Survival of spot-seeded northern red oak (Quercus rubra), chestnut oak (Quercus prinus), pin oak (Quercus palustris) and Virginia pine (Pinus virginiana) on minesoil in southeastern Kentucky increased by 22 percent when treated with 2.5 cm of shredded bark and a 9 g fertilizer tablet (18% N-8% $P_2O_5$ - 3% $K_2O$ - 1% mg). First year height growth was increased by approximately 85 percent when the bark mulch and fertilizer tablets were used.[4] Loblolly pine (Pinus taeda), longleaf pine (Pinus palustris), and slash pine (Pinus elliottii) were successfully direct-seeded on minesoil in Alabama. It was estimated that by aerial seeding, the total costs ran about one-third that of hand planting seedlings.[5]

## SECTION 2

## CONCLUSIONS

Large-seeded species such as oaks appear to be better suited for direct-seeding of minesoil than the small-seeded species such as Paulownia and E. alder. Stratifying the alder seed and subjecting them to light before seeding should improve their success in the field. Germination of Paulownia seeds might have been increased by a pre-germination light treatment to reduce their high light requirement.

Highest germination, survival and best growth for all species occurred on the southeast facing aspect which exhibited higher minesoil temperatures and contained higher minesoil moisture. Germination of tree seeds was enhanced by mulching with bark/manure, Real Earth or bark, as it contained more moisture than either the control or w.f.m. plots. Seedlings mulched with bark/manure exhibited the best growth, probably because of additional nutrients. Mulching effects on height growth were not significantly different from the control after the second growing season. Fertilizer additions decreased germination by aiding the growth of ryegrass and sweetclover which out-competed the seeds for light, minesoil moisture and nutrients. Height growth of the seedlings was not significantly affected by fertilizer treatments. Height growth decreased as herbaceous species seeding rates increased. These results suggest that successful direct-seeding of oaks on minesoil can be achieved and that better germination may be obtained by mulching with bark/manure or Real Earth. Planting less competitive grasses and legumes in combination with tree seeds may help improve both germination and survival.

## SECTION 3

## RECOMMENDATIONS

Various treatments of mulch, fertilizer and herbaceous cover will affect tree growth and survival in many different ways. Tree growth relative to other types of plants exhibit slow growth characteristics; therefore, certain effects of these treatments may not appear for several years. For this reason, the research in this report should be continued. Data contained in this report only covers initial establishment of tree seedlings and no clear picture of treatment effects on survival and growth can be made without data from five to ten years.

## SECTION 4

## METHODS

Plots were established in March 1978 on minesoil near Jackson, Kentucky. The purpose of the study was to investigate the potential use of direct-seeding as a silvicultural tool on minesoil. Paulownia (Paulownia tomentosa) European alder (Alnus glutinosa), northern red oak (Quercus rubra), pin oak (Quercus palustris) and bur oak (Quercus macrocarpa) were direct-seeded in combination with several treatments on freshly disked minesoil.

A split-plot design was replicated twice on three aspects - ridge, northwest (335°) and southwest (155°). On each aspect 15.5 m by 15.8 m plots were replicated twice and treated with one of the following treatments, selected at random.

(1) Control - no mulch applied.

(2) Waterborne fiber mulch - processed wood fiber, 560 kg/ha.

(3) Processed bark - 66 $m^3$/ha.

(4) Processed bark and chicken manure - 66 $m^3$/ha.

(5) Real Earth - composted solid municipal waste and sewage sludge, 27 mt/ha.

Each plot was split in half into species subplots 7.3 m by 15.5 m and each was seeded with tree seed after all other treatments were applied. The sublots were further subdivided into three fertilizer subplots, 5.2 m by 7.3 m, and treated with fertilizers (0, 224, or 448 kg/ha of 16% N, 32% $P_2O_5$, 8% $K_2O$). The fertilizer subplots were divided in half with each half containing three 1.2 m by 1.2 m competition plots spaced .6 m apart. Either 0, 11 or 22 kg/ha of a one-to-one mixture of yellow sweetclover (Melilotus officinalis) and tetrablend ryegrass (Lolium perenne) were broadcast seeded onto each subplot.

Germination tests results on European alder and Paulownia seeds conducted prior to the field trials were used to determine seeding rates. Paulownia seeds were collected in southeastern Kentucky in 1976 and dry stored at 4°C. Approximately 80 percent of the Paulownia seeds tested germinated within 30 days when exposed to light. The seeding rate for Paulownia was ten seeds per spot. The seeds were placed in small depressions and covered lightly with mulch or minesoil material. The total number of Paulownia seed-spots was 1080.

European alder seeds were planted by mixing the seeds with sand and broadcasting them onto their respective subplots. European alder seeds were acquired from a commercial source and were not stratified before seeding. Only 32 percent of the seeds germinated when exposed to light and kept moistened. The seeding rate for alder was approximately 2 grams per subplot or 10 seeds per one tenth meter square. The oak seeds used in the study were collected in the Lexington area. For northern red oak, bur oak and pin oak, one acorn was placed in each planting hole. The number of seed-spots for each species was northern red oak - 540, bur oak - 360 and pin oak - 270. Germination was evaluated in mid-July by tallying the number of seed-spots containing live seedlings. Growth and survival were tallied in late September 1978 and early October 1979. The Neutron probe was used to determine minesoil moisture. Minesoil temperatures were monitored with Coleman soil moisture-temperature cells.

## SECTION 5

## RESULTS AND DISCUSSION

### GERMINATION AND SURVIVAL

Of the five species tested, the large-seeded species appeared to be most adapted for direct-seeding of minesoil. The oak species averaged 43.0 percent germination over all treatments. Bur oak germinated best at 50.0 percent followed by pin oak and northern red oak with 46.0 and 34.0 percent respectively (Table 1). Paulownia germination was only one percent and European alder failed completely. Seedling mortality was observed during the second growing season, resulting in 94.4 percent survival for northern red oak and 92.0 percent survival for pin oak. Bur oak increased over-all germination from 41.0 percent to 50.0 percent during the second growing season.

TABLE 1. MEAN PERCENT GERMINATION AND HEIGHT OF FIVE SPECIES DIRECT-SEEDED ON EASTERN KENTUCKY MINE SPOIL AFTER TWO GROWING SEASONS (1978 and 1979)

| Species | Mean germination (percent) | | Mean height (cm) | |
|---|---|---|---|---|
| | 1978 | 1979 | 1978 | 1979 |
| European alder | 0 | 0 | 0.0 | 0.0 |
| Paulownia | 1 | 1 | 11.3 | 65.0 |
| Northern red oak | 36 | 34 | 5.5 | 9.2 |
| Bur oak | 41 | 50 | 8.5 | 12.5 |
| Pin oak | 50 | 46 | 8.3 | 12.1 |

Percent survival for paulownia, northern red oak, bur oak, pin oak was higher on the southeast facing slope (109 percent) than the ridge (97 percent) or the northwest facing aspect (98 percent) (Table 2). Percentages over 100 were caused by late germination of bur oak during the second growing season. Two factors appear to be underlying this response. First, spoil samples collected from each aspect site revealed that the southeastern exposed site contained more nitrogen, phosphorus and potassium than either the ridge or northwest facing sites. Secondly, the southwest facing plots contained significantly ($p<0.05$) greater spoil moisture and exhibited higher spoil temperatures than the other two sites. The results indicate that both factors enhanced the germination and survival of tree seeds on that site.

Mulching with Real Earth or bark/manure increased seed germination by over 5 percent when compared to bark, w.f.m. or the control plots. Response to the mulching treatments probably was due to the individual capacities of

TABLE 2. SINGLE VARIABLE EFFECTS OF ASPECT, MULCH, FERTILIZER AND GRASS-LEGUME COMPETITION OF MEAN GERMINATION AND HEIGHT GROWTH OF DIRECT-SEEDED PAULOWNIA, NORTHERN RED OAK, BUR OAK AND PIN OAK AFTER TWO GROWING SEASONS (1978 and 1979) ON EASTERN KENTUCKY MINE-SPOIL

| Variable | Germination 1978 | | Survival 1979 | Height Growth(cm) | |
|---|---|---|---|---|---|
| | P F[1] | Percent | Percent[4] | P F 1978[5] | 1979 |
| Aspect | 0.01** | | | 0.10 | |
| northwest | | 26 | 98 | 7.4 | 11.6 |
| ridge | | 30 | 97 | 7.0 | 9.8 |
| southeast | | 39 | 109 | 7.8 | 12.4 |
| Mulch | 0.15 | | | 0.10 | |
| control | | 29 | 103 | 7.0 | 10.8 |
| hydromulch | | 29 | 107 | 7.0 | 12.0 |
| bark | | 29 | 110 | 7.6 | 11.6 |
| bark/manure | | 34 | 101 | 8.4 | 12.1 |
| Real Earth | | 36 | 99 | 7.1 | 11.1 |
| Fertilizer | 0.06* | | | 0.10 | |
| 0[2] | | 34 | 104 | 6.9 | 11.1 |
| 224 | | 30 | 101 | 6.9 | 11.8 |
| 448 | | 30 | 108 | 7.5 | 11.9 |
| Competition | 0.10** | | | 0.10 | |
| 0[3] | | 37 | 103 | 7.2 | 12.5 |
| 11 | | 27 | 107 | 7.2 | 11.1 |
| 22 | | 30 | 105 | 7.2 | 10.7 |

1/ *Denotes slight significance.
**Denotes highly significant response.
1979 Data not analyzed statistically.

2/ Fertilizer rates expressed in Kg per ha.

3/ Seed rates expressed in KG per ha.

4/ Percentages over 100 caused by late germination of bur oak during second growing season.

5/ 1978 Height growth average over all species.
1979 Height growth averaged over oak species only.
Paulownia excluded because of low survival.

the mulches to hold moisture. During the first growing season, significantly less minesoil moisture was observed in the w.f.m. and control plots than Real Earth or bark/manure. Surface minesoil moisture was not a factor during the second growing season, because of a record rainfall in Kentucky during 1979. Also mulches tend to become less effective in moisture conservation with time.

Germination was affected slightly by additions of fertilizer. Germination decreased from 34 to 30 percent when either 224 or 448 kg/ha fertilizer rates were applied. These results suggest that the grass and legume species responded rapidly to the fertilizer and consequently shaded the tree seed, preventing light from reaching the seeds. Overall survival was not affected by fertilizer treatments.

Seeding a grass-legume cover at the time of direct-seeding appeared to affect germination more than any other variable tested. Seeding a grass-legume cover at 11 kg/ha decreased germination from 37 to 27 percent. Again grasses, especially ryegrass, germinates and becomes established quicker than tree seeds, robbing them of light, moisture and soil nutrients. Doubling the seeding rate to 22 kg/ha resulted in a slight increase in germination (30 percent) over the lower seed rate used. Herbaceous cover did not appear to effect survival.

## HEIGHT GROWTH

As expected, the paulownia seedlings that survived grew tallest averaging 65.0 cm after the second growing season. Bur oak and pin oak grew moderately well with 12.5 and 12.1 cm respectively, while northern red oak seedlings averaged 9.1 cm.

The results in Table 2 indicate the growth response of seedlings to the various treatments. Although the differences in growth observed between aspect sites were not significant, seedlings on the southeast grew best. These differences in growth were probably due to better moisture and minesoil fertility of that site.

Seedlings mulched with bark/manure were taller (8.4 cm) than seedlings mulched with any other material. The additional nutrients provided in the mulch may account for the increase in growth. However, the use of mulch did not affect height growth during the second year. Fertilizing with 448 kg/ha increased height growth slightly over the 224 kg/ha treatment of the control. Herbaceous cover did not significantly affect height growth in the first growing season. It did appear to have a negative effect on growth the second season with increased seeding rates of herbaceous species.

## REFERENCES


1. H. J. Derr and W. F. Mann, Jr., "Direct-seeding pines in the South", USDA Agric. Handb. 391, 66pp., 1971.

2. H. L. Williston and W. E. Balmer, "Direct-seeding of southern pines - a regeneration alternative", USDA For. Serv. SE For. Mgt. Bull. 6pp., Apr. 1977.

3. G. A. Limstrom, "Extent, character and forestation possibilities of land stripped for coal in the Central States", USDA For. Serv. CS Tech. Pap. No. 109. 79pp., 1948.

4. R. F. Wittwer, D. H. Graves and S. B. Carpenter, "Establishing oaks and Virginia pine on Appalachian surface-mined lands by direct seeding", Reclamation Review (In press), 1979.

5. T. Wiseman, "Hitting pay dirt with pine seeds: strip mines reforested". Mining Cong. J. pp. 59-60, Dec. 1978.